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Individual Cooling Systems Results and Quantified Performances Using an Objective Method

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Summary

The evaluation of individual thermal assistance equipment can be quantified through numerous parameters. However, to assert efficiency and interest for a military user under tropical climate, it is necessary to follow a quantifying method.

This process of existing and prototyped measurements, based on simulations, with a dummy man and tests with voluntary subjects, using a scale of comparison. It has been clearly defined and used to evaluate of more as 10 systems, It allows to know the limits of each technology and the actual perspectives for equipment that are really suitable for the user.

This original method based on operational ergonomic and technical criteria take into account weight, efficiency linked with the work load, infrared and sound signature, life as well as the logistic needed for the use of these different equipment.

A complementary study of commercially available equipment, allows to compare and classify these equipment according to the same method. It allows the user to choose a suitable equipment to put eventually in service for overseas forces.

1. Introduction

The protection of human working in hazardous and extreme climatic conditions requires particular protective clothing. These equipment decrease the physical capabilities and the physiological ability to payload and could need a thermal assistance to allow the achievement of the mission.

Before testing in real scale on human, it is necessary to be sure of the reality and efficiency of the performances of the dedicated equipment. For this purpose, a progressive method has been previously described, using a thermal and instrumented manikin to measure the efficiency of thermal cooling systems and, in a second step, laboratory testing on human.

A testing procedure is still necessary to verify if the equipment can achieve the protection and cooling assistance requirement before their qualification.

2. Method

2.1. Suit insulation and cooling power measurement.

The measurement of the insulation of the thermal assistance suit is generally performed with a thermal manikin in specific conditions (after ASTM 1291-90).

The measurement system includes :
- a climatic chamber,
- an instrumented and thermal manikin, monitored by a computer.

Paper presented at the RTO HFM Symposium on "Blowing Hot and Cold: Protecting Against Climatic Extremes", held in Dresden, Germany, 8-10 October 2001, and published in RTO-MP-076.

This method is well adapted to the quick measurement of clothing insulation (Clo) which is a characteristic of the suit and of the cooling system. It allows to measure the power really provided by the system to the manikin and eventually the response time due to thermal storage. By both measurement of the modification of suit insulation and of the powerful of the individual cooling system, the instrumented manikin is used in similar condition when measuring global suit insulation and thermal transfer.

The measurement protocol includes two successive steps. The first (15 minutes duration) is performed with the non operating thermal cooling system in order to measure the total insulation of equipment and the heating power of the manikin at thermal balance. The second, (variable duration according to the autonomy of the tested cooling device) is realised in normal operating mode of the system. The power modification in order to keep the thermal balance and the measurement of skin temperatures allow to characterise precisely the tested cooling system.

2.2. Laboratory test protocol on volunteers

The voluntary experimented people, regular soldiers, are informed on the interest of the experimentation.

Each people realise every two days in regular simulated tropical climatic environment (Ta= 35 °C, Hr= 40%, wind speed 1 m/s) the following protocol :

- 20 minutes of seated rest,
- 30 minutes of walk on a treadmill, (4 km/h, 0% slope)
- 10 minutes of seated rest
- 30 minutes of walk on a treadmill, (4 km/h, 0% slope)
- 30 minutes of seated recovery.

The trial begins by a reference test using protective equipment without any thermal assistance, and continue with the same suit plus the cooling equipment. The experimented people do not drink during the tests.

The physiological measurements include :

- rectal and skin temperature (Ramanathan method),
- cardiac signal and frequency issued from the cardiac signal,
- sweat loss and sweat weight fixed in each element of the suit,
- an evaluation using a questionnaire filled by the experimented people after each test.

2.3. Tested cooling devices

More as 10 different types of individual cooling system have been tested. The cooling process was a demonstrative panel of technologies using blowers with or without a complementary cooling device, such as ice packs (using water or CO^2), zeolite exchangers and gas compression systems. Transfer suit (jacket, 2 pieces undergarment) are specially designed for air or water circulation.

3. Results

By using laboratory data obtained with the thermal manikin, laboratory results on human, some times field trial results and for a few number of systems, information issued from scientific publications (non commercial data), the table of pertinent parameters is filled.

On the basis of these information, a first global and comparative report can be made, describing effective efficiency of each equipment. So it becomes possible to compare these final values with those provided by commercial equipment. The following tables give some information on technical characteristics and results concerning tested equipments.

All results were obtained with the same impermeable decontamination suit and with different individual cooling systems at 35°C and 40% relative humidity.

	Weight kg	Total Power W	Autonomy min	Noise dBa
Compression	10-13	120-160	40-120	65
Blowers	3.5-7	110-240	80-240	58
Ice packs	3-8	80-160	40-170	0-48
Zeolite-air	11-14	110-285	55-120	60-68

Table 1 : Main physical parameters of individual cooling systems.

	Effective power W	Power/weight W/kg	Jacket Weight kg	Insulation Clo
Compression	78-110	12-13	2.4-3.4	1.0-1.3
Blowers	95-220	31-47	0.65-1.10	0.80-0.95
Ice packs	95-150	26-53	1.6-6.2	0.79-1.0
Zeolite-air	55-235	8-25	1.00-1.10	0.98-1.2

Table 2 : Effective technical parameters of individual cooling systems.

	Effective power W	Sweat loss kg	Sweat rate Kg/h	Thermal storage Kj/m²
Compression	78-110	0.800	0.54	284
Blowers	95-220	0.83-1.20	0.5-0.55	225-270
Ice packs	95-150	0.55-1.2	0.39-0.53	274-330
Zeolite-air	55-235	1.15	0.54	220

Table 3 : Measured thermal parameters on human.

4. Conclusion

Using an instrumented thermal manikin and volunteers in laboratory, the measurements of the efficiency of individual thermal cooling systems has been performed. Through a very simple protocol, using dummy man, it allows to measure elementary parameters, like the modification of insulation due to the transfer jacket, the power really transferred to the user, and the autonomy. The test with the thermal and instrumented manikin is the indispensable preliminary step before trial on human in laboratory or on the field under extreme climatic ambience.

During laboratory testing on volunteers, heart rate, body temperatures and thermal storage measurement allow to determine employment security limits of these individual cooling systems.

Moreover this gradual method gives technical parameters that allow to compare different technologies of thermal cooling system in similar and easy to be reproduced conditions.

Comparing different technologies, cooling systems using blowers to favour sweat evaporation, give the best ratio “effective power/supplementary work load” accepted by man. Nevertheless new developments must involve advanced technologies in order to obtain good results in very hot and humid conditions.

5. References

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